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Geotechnical investigation and testing — Field testing —

Part 15: Measuring while drilling

Reconnaissance et essais — Essais de sol —

Partie 15: Enregistrement des paramètre de forages

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Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

ISO 22476-15 was prepared by the European Committee for Standardization (CEN) in collaboration with ISO/TC 182, *Geotechnics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

A list of all parts in the ISO 22476 series, published under the general title *Geotechnical investigation and testing — Field testing*, can be found on the ISO website.

Introduction

The measuring-while-drilling (MWD) method deals with the recording of the machine parameters during the drilling process. This can be done manually or with the use of computerized systems which monitor a series of sensors installed on rotary and/or percussive drilling equipment. These sensors continuously and automatically collect data on all aspects of drilling, in real time, without interfering with the drilling progress. The data are displayed in real time and are also recorded for further analysis. Examples for interpretation of the results are presented in Annex A.

The borehole can be used for other applications such as installation of monitoring equipment, geophysical logging or realization of expansion tests. The interpretation of the MWD results can be done in relation with the information provided by sampling.

It should be noted that measured and calculated drilling parameters are relative and dependant of the test conditions, procedures and equipment.

Geotechnical investigation and testing — Field testing —

Part 15: Measuring while drilling

1 Scope

This part of ISO 22476 specifies the technical principles for measuring equipment requirements, the execution and reporting on the parameters of the investigation drilling process for geotechnical purposes.

It is applicable to top-driven, destructive drilling methods performed by a fully hydraulically powered drill rig and driving device. It is commonly used with destructive drilling techniques but can also be used with core drilling.

The recording of the drilling parameters during soil grouting, drilling of nails, anchors or piles are beyond the scope of this part of ISO 22476.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 14688-1, *Geotechnical investigation and testing — Identification and classification of soil — Part 1: Identification and description*

ISO 14689-1, *Geotechnical investigation and testing — Identification and classification of rock — Part 1: Identification and description*

ISO 22475-1, *Geotechnical investigation and testing — Sampling methods and ground water measurements — Part 1: Technical principles for execution*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 22475-1 and the following apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at http://www.electropedia.org/

— ISO Online browsing platform: available at http://www.iso.org/obp

3.1
drilling parameters
parameters measured and recorded on the drill rig during drilling (mainly hydraulic pressures, depth, penetration rate, rotation speed, fluid pressure and flow, etc.)

3.2
compound parameters
parameters derived from the combination of a number of the drilling parameters

3.3
reflected vibration
acceleration due to elastic rebound of rods compressed by hammer impact

3.4
penetration length
length measured along the axis of the borehole between ground level and the drilling tool

3.5
penetration rate
rate of penetration of drilling tool into the ground

3.6
down thrust pressure
thrust pressure applied to drilling tool

3.7
holdback pressure
pressure limiting penetration rate due to safety requirements

3.8
flushing medium pressure
pressure at the level of the drilling tool

3.9
torque
drill head rotational torque

3.10
rotation speed
drill head rotational speed

3.11
flushing medium circulation rate
rate of output of drilling tool down the hole

4 Symbols

Symbol	Name	Unit
a	measured penetration length	m
α	efficiency coefficient of down-thrust work	—
β	efficiency coefficient of torque work	—
γ	efficiency coefficient of hammering work	—
C_R	measured drill head torque	kN·m
$C_{R\,max}$	maximum measured drill head torque	kN·m
d_o	external diameter of drill bit	mm
E	calculated drilling energy	J
E_S	calculated specific energy	J
E_R	measured reflected vibrations	J
f	hammer frequency	Hz
F_{max}	maximum down thrust force	kN
H_{max}	maximum hold back force	kN
I_A	calculated alteration index	—
N	quantity of rods	—
p	measured hydraulic pressure in feed motor or cylinder	MPa

Symbol	Name	Unit
p_{CR}	measured hydraulic pressure in torque motor	MPa
p_{CRO}	unloaded torque motor pressure	MPa
$p_{CR\,max}$	maximum measured hydraulic pressure in torque motor	MPa
p_H	measured hold back pressure	MPa
p_I	calculated flushing medium pressure at output of the drilling tool	MPa
p_E	calculated net down-thrust (or feed thrust) applied on drilling tool	MPa
p_F	measured flushing medium pressure at output of the pump	MPa
p_M	measured hammering pressure	MPa
p_{max}	maximum measured down-thrust pressure	MPa
p_O	raw down-thrust (or feed thrust) applied on drilling tool	MPa
p_{HC}	calculated holdback pressure	MPa
$p_{H\,max}$	maximum measured holdback pressure	MPa
P_R	penetration resistance	s/0,2 m
Q_I	measured borehole drilling fluid inflow	l/min
Q_O	measured borehole drilling fluid outflow	l/min
R_{SR}	calculated soil-rock resistance	MPa m^{-1} s^{-1}
S_d	calculated Somerton index	—
s_O	measured area removed by drill bit (= drilling tool surface)	m^2
t	measured time	s
v_A	penetration rate	m/h
v_R	measured drill head rotational speed	r/min
W_H	weight of rotary head	kN
W_R	weight of drill rod	kN
Z	measured depth	m
r_w	measured ground water table depth	m

5 Equipment

5.1 General

Drilling parameters can be considered as being in one of three categories.

— Parameters imposed by the method (type of drilling tool and diameter, nature of the fluid medium, limits of machine performance and injection system) and unmanaged scalable parameters (tools wear, changes in the composition of the fluid).

— Parameters set by the operator (p_O down-thrust, v_R drill head rotational speed, Q_I flushing medium circulation rate in the case of an incompressible or water based drilling fluid, p_I injection pressure in the case of a compressible air based fluid),

— Parameters depending on the response of the ground (v_A penetration rate, C_R torque, p_I injection pressure in the case of an incompressible or water based fluid, Q_I flushing medium circulation rate in the case of a compressible air-based fluid),

These parameters may be measured directly or calculated using calibration relations. Further compound parameters may be derived by combining a number of drilling parameters (see A.2.)

5.2 Drilling equipment

Drilling machines with appropriate stability, power and equipment such as drilling rods and bits shall be selected in order to achieve the required depth and stability of the borehole. The drilling equipment shall be of the appropriate size and type in order to produce the required quality of MWD test. The drilling rig and equipment shall allow all drilling functions to be adjusted accurately.

The drill rig shall be chosen based on the project objectives with sufficient capacity to penetrate the various geologic layers and equipped with the appropriate drilling tools.

Drill head and feed mechanism shall be hydraulically operated to allow drilling parameter monitoring.

Only top hammer drilling shall be used. The equipment shall be loaded or anchored to limit movements of the drilling machine relative to ground level while the penetration occurs.

The drilling flow pump shall comply with the following characteristics:

— provide a constant flow independent of the pressure, pumps creating pulsation shall be avoided (e.g. single piston pump);

— achieve a minimum pressure of 3 MPa (unless otherwise noted);

— have a sensitive and calibrated pressure gauge mounted directly on the pump outflow;

— allow a 0,8 m/s to 1 m/s cutting return (depending on fluid viscosity).

Prior to each use, the straightness of rods shall be checked visually. The deviation of the linearity of the rods shall not exceed 5 mm from the centreline for 3 m long rod. The straightness of the push rods shall be determined at regular intervals.

The drilling tool used for MWD method shall be drill bit type acting in rotary or rotary percussion drilling. The use for other drilling technique shall be avoided.

5.3 Measuring system

5.3.1 General

The automatic measurement system shall include

— a data recorder incorporating a data display,

— a data acquisition system including a signal converter (sometime part of data recorder), and

— transducers set on the machine.

Depending upon the MWD application class (see 5.4), the influence of the positioning of sensors on the recorded measurements shall be minimized.

The manual measurement shall include

— depth according to time or time for a penetration of 0,2 m, and

— parameters read by the operator on gauges.

The measuring system shall give a real-time display of the readings to allow adjustments to the drilling process according to the observed progress of the test.

The measuring equipment shall be checked and/or calibrated regularly according to the manufacturers' specification. The results of the checking and/or calibration shall be reported (see Clause 7). If any part of the system is repaired or exchanged, calibration shall be verified.

Calibration of all sensors shall be performed at the following interval:

— yearly, if certifications are made by third-party control (for instance, manufacturer) at regular interval;

— at least every six months by internal control.

A calibration report should be generated and a copy of the report should be kept with the maintenance log. A copy of the latest calibration test report shall be available at the job site.

5.3.2 Sensors for hydraulic pressures

The following pressures shall be measured:

a) down-thrust pressure p and torque pressure p_{CR};

b) holdback pressure p_H (complementary to the down-thrust, this pressure p_H shall be measured to calculate the net down-thrust applied on the bit; holdback pressure is the hydraulic pressure prevailing in the return line);

NOTE 1 Differential pressure transducer can be used to measure the net down thrust directly.

NOTE 2 Down-thrust force can be directly measured by load sensor.

c) flushing medium pressure p_F.

Measurement of this pressure shall be performed in the manual procedure on pressure gauges and in the automatic procedure using transducers placed on the flush line.

5.3.3 Measuring system for penetration length

Measurement of drilling tool penetration length shall be performed between the top of the mast and the drill rod.

The penetration length shall be determined through the following methods:

— automatic, using a rotary encoder fitted on the feed motor axis, a chain/cable attached between the fixed mast and moving drill-head, a wheel fitted the drill head and running against the mast or other suitable method;

— manual, using a tape.

5.3.4 Measuring system for flushing medium flow

Flow shall be measured using a flow meter. Its accuracy and calibration shall be documented as part of the report.

NOTE The measurement of the drilling fluid return flow (outflow), Q_O, at the exit of the borehole can provide an estimation of the volume of fluid exchanged (absorbed or provided from confined aquifer) within the ground.

5.3.5 Measuring system for rotational speed

Rotational speed (v_R) measurement shall be done through the following methods:

— manual procedure using a tachometer;

— automatic procedure using a rotation or proximity sensor that counts the passage of a metallic element.

5.3.6 Measuring of hammering energy

Hammering energy shall be measured using a pressure transducer to measure the pressure p_M used to activate the hammer and the blow frequency, f (alternatively determined by a flow meter).

5.3.7 Reflected vibrations

Vibration due to percussive reflected waves generated when the hammer hits the anvil (E_R) which descends and ascends after reflection in the end of the rods may be measured with an accelerometer. This signal is disturbed by stray reflections to each new stem, natural attenuation of the signal, and so on.

5.3.8 Time

Measuring the time, t, shall be performed using the following methods:

— manual procedure using a stop watch;

— automatic procedure using the internal clock of the data acquisition system and corresponds to a detection time of a new depth step.

5.4 Selection of measured parameters

Depending on the number of parameters measured while drilling, three quality classes of MWD measurements are defined (see Table 1):

— quality class 1, where six or more parameters are measured;

— quality class 2, where four or five parameters are measured;

— quality class 3, where at least two parameters are measured.

The following drill parameters may be measured:

— penetration length;

— down-thrust pressure in feed motor or cylinder;

— holdback pressure;

— torque pressure in motor;

— flushing medium pressure;

— drill head rotational speed;

— flushing medium circulation rate.

The fluid flow, as well as the total drilling fluid volume for each boring, should be recorded.

In the case of rotary percussion, reflected vibrations, E_R may be measured.

Instead of penetration length, a, the operator can use penetration rate, v_A, given by the measuring system to control the machine (see 5.3).

For all quality classes, the parameters measured shall always include the measured penetration length, a, and the down-thrust pressure, p, in feed motor or cylinder except for Quality Class 3 manual recording when p shall be replaced by penetration resistance, p_R. Additional parameters shall be selected to meet the particular requirements of the investigation.

